THE EFFECT OF TEMPERATURE ON SEVERAL FACTORS INFLUENCING THE TOXICITY OF DDT TO *PERIPLANETA AMERICANA* (L.)

BY

EDDIE BORDERS VINSON

B.S., Alabama Polytechnic Institute, 1948
M.S., Alabama Polytechnic Institute, 1949

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN ENTOMOLOGY
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Introduction

Various workers have reported a negative temperature coefficient of action for DDT (1,1,1-trichloro-2,2-bis-(*p*-chlorophenyl)ethane) used as a contact poison against several species of insects. Pradhan (1949) reviewed most of the reports, and reconciled the results of all workers by concluding that the rise or fall in toxicity of any contact poison with temperature change was the resultant of two opposing factors, namely, absorption (including "pick-up" of poison from residual deposits and the subsequent penetration) and physiological resistance of the insect (including detoxification and elimination of the poison). Insufficient parallel injection experiments have been reported to warrant evaluation of the relative effects of absorption and physiological resistance, at different temperatures, on the toxic action of DDT. This investigation was started with the purpose to determine the quantitative effects of temperature on the rates of penetration and metabolism of topically-applied doses of DDT and on the rate of metabolism of injected doses of DDT in American cockroaches. The results of this study revealed that the effect of temperature on the interactive forces of penetration and metabolism was not sufficient to explain the negative temperture coefficient of action of topical and injected doses of DDT. Roeder and Weiant (1946) have shown the main initial effect of DDT to be an increase in frequency of electrical activity in sensory nerves. Therefore, the latter part of this investigation is devoted to a study of the effect of temperature on the electrical activity of the intact nerve cord of DDT-treated roaches; the activity in the nerve cord was assumed to be a measure of the ganglionic and interganglionic responses to DDT-induced afferent stimulation.

Methods

Preliminary experiments at room temperature (23-28°C.) were conducted to determine the metabolic fate of oral and topical doses of DDT in female American cockroaches. Chemical analyses of various body tissues and excreta were made using essentially the same method employed by Sternburg *et al* (1950) for house flies.

The toxicity and relative rates of penetration and metabolism of injected and topical doses of DDT were determined using female American cockroaches that were kept at 15°C. and 35°C., respectively, for various intervals after treatment. Chemical analyses of treated roaches were made in the same manner employed for preliminary experiments with the exception that DDT and certain metabolites were separated prior to analysis by the chromatographic method of Sternburg and Kearns (Unpublished).

Oscillographic studies of electrical activity at 15°C. and 35°C. were made using a cathode ray oscillograph and silver recording electrodes. Temperature control was accomplished by placing the test roach in a square asbestos box lined with coiled copper tubing through which was pumped hot or ice-cold water as desired; the electrodes were fitted into the cover of the box. One constant temperature could be maintained with fluctuations of 1 to 2°C., and changes from one temperature to another were made in 2 to 5 minutes.

Summary and Conclusions

Experiments at room temperature: Orally-administered DDT is confined mainly to the fore-gut prior to detoxification and elimination; lack of penetration to other tissues may account for the lack of toxic effectiveness of oral doses of DDT. Topical doses of DDT are absorbed very slowly when applied to the sclerotized tergites of the abdomen. Oral and topical doses of DDT are metabolized to DDE (1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene) and unidentified metabolites.

Analytical and observational studies at 15°C. and 35°C.: Injected and topical doses of DDT show negative temperature coefficients of action between 15°C. and 35°C. The effect of temperature in changing the equilibrium between the competing forces of penetration and detoxification of topically-applied DDT does not account for the negative temperature coefficient of action of DDT. Larger amounts of DDT are absorbed and metabolized at 35°C. than at 15°C. The percentage metabolism of absorbed DDT, however, is approximately equal at the two temperatures when equivalent dosages are compared. Injected doses of DDT greater than the LD-50 dose at 15°C. but smaller than the LD-50 dose at 35°C. cause prostration, within 1 hour, of roaches kept at 15°C. but do not seriously affect roaches kept at 35°C. Transfer of treated roaches from one temperature to the other results in reversal of poisoning symptoms; the time required before prostration becomes irreversible at 15°C. decreases with increasing dosages of DDT. The initial rate of metabolism of injected doses of DDT after injection is determined by two factors, namely, DDT concentration and the detoxification potential (sum of factors that act to metabolize DDT) of the roach. An intermediate optimum dosage of DDT results in maximum initial metabolism at either temperature; metabolism of doses smaller than the optimum is limited by the concentration of DDT while metabolism of larger doses is limited by the detoxification potential. The detoxification potential is not changed with increasing doses of DDT (8 to 20 ug.) at 35°C. but is lowered by the larger doses at 15°C. The lower rate of metabolism of large injected doses of DDT at low temperatures is interpreted as being the result of the increased effectiveness of DDT in disrupting all body functions, including those processes responsible for the metabolism of DDT. Thus, the negative temperature coefficient of action of DDT must be based on the effect of temperature on the intrinsic susceptibility of some physiological system. Two metabolites of DDT, one identified as DDE and an unidentified metabolite called Metabolite X, are recoverable from DDT-treated roaches. Large amounts of both metabolites are found in

roaches kept at 35°C. but the total of both metabolites at either temperature does not account for the metabolized portion of DDT.

Oscillographic studies: Roaches treated with an injected dose of DDT causing prostration at 15°C., which can be reversed to normalcy within 15 minutes by changing the temperature to 35°C., and vice versa, show similarly reversible patterns of electrical activity in the intact nerve cord. Roaches treated with a dose of DDT producing irreversible prostration at either 15°C. or 35°C. show similar initial increases in electrical activity of the intact nerve cord but different subsequent changes; blocking of practically all activity occurs within 1 hour at 15°C. but is delayed for longer than 2 hours at 35°C. The tentative interpretation is made that the increased effectiveness of DDT in producing prostration of roaches at low temperatures may be due to the difference in response of the central nervous system to DDT-induced afferent stimulation.

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VITA

Eddie Borders Vinson, son of Vera Norton and Eddie Borders Vinson, Sr., was born at Louisville, Alabama, March 7, 1926. After graduating from Louisville High School in January, 1942, he attended Alabama Polytechnic Institute until June, 1944. He was inducted into the Army in September, 1944, and served until July, 1946. While in the European Theatre of Operations, he attended the Biarritz American University, Biarritz, France from October, 1945, to December, 1945. He returned to Alabama Polytechnic Institute in September, 1946, and received the degree of Bachelor of Science in Agricultural Science in June, 1948. He and Miss Marie Nunnelley were married in February, 1948. He was employed by the Alabama Agricultural Experiment Station as Assistant to the Entomologist during the summers of 1947 and 1948. In September, 1948, he enrolled in the Graduate College of Alabama Polytechnic Institute and received the degree of Master of Science in Entomology in December, 1949. He enrolled in the Graduate College of the University of Illinois in February, 1950, and has held a University Fellowship since that time.

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